

# Long-term monitoring of Blazars – the DWARF network

Blazars hosting Binary Black Holes?  
Blazars as hadronic accelerators?  
DWARF: A global IACT network  
The DWARF telescope  
Summary

**Michael Backes**  
**for the DWARF collaboration**

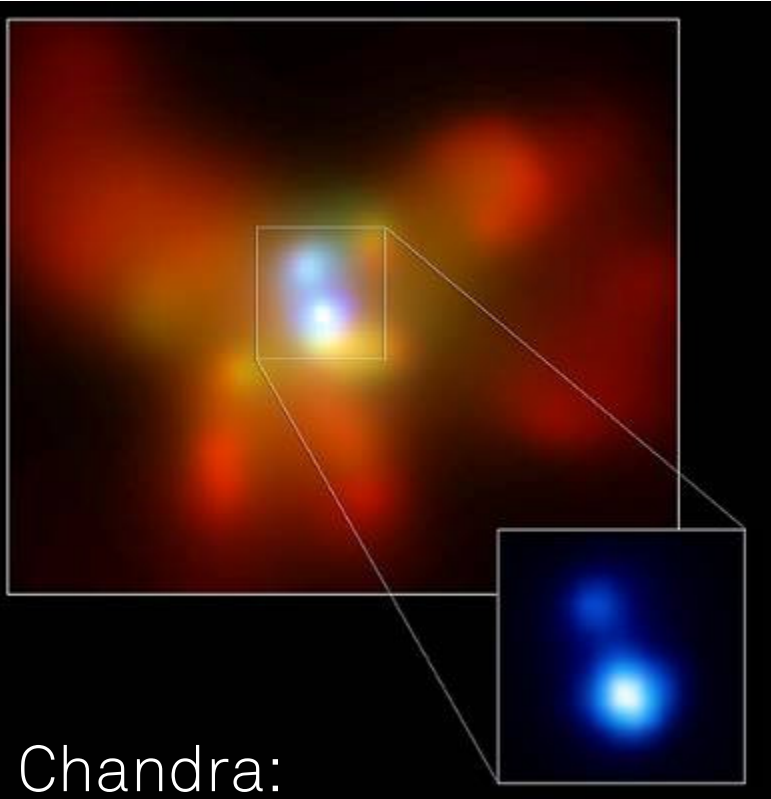
Acknowledging support of



Deutscher Akademischer Austausch Dienst  
German Academic Exchange Service



Michael Backes for the DWARF collaboration  
12/09/2009 | Smithsonian Astrophysical Observatory



Chandra:

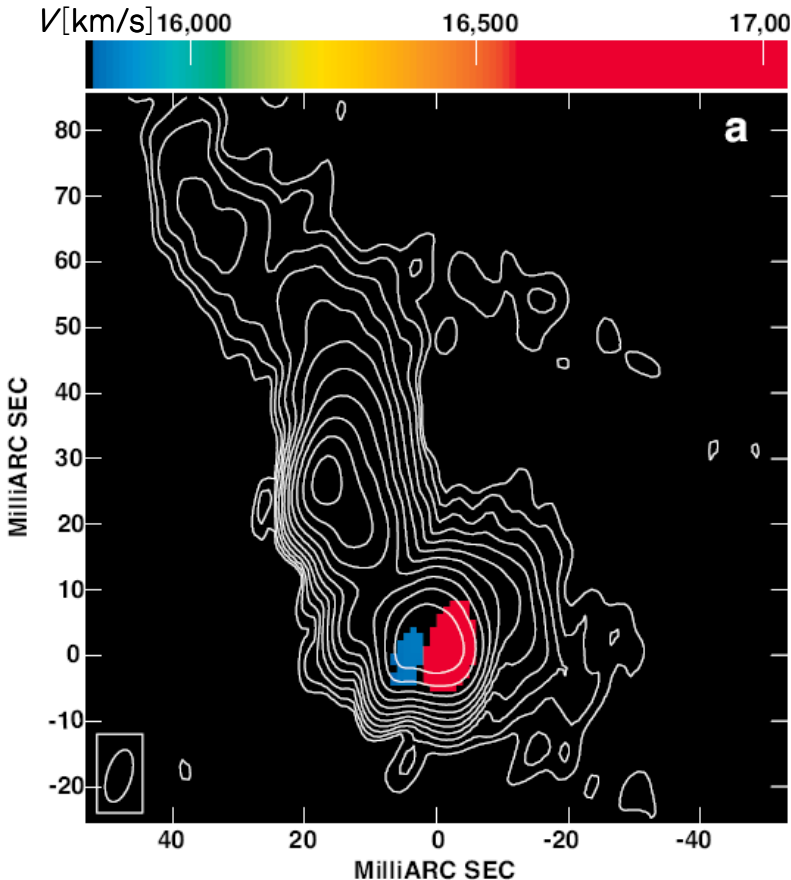
NGC 6240:  $z=0.024$ ;

$d \sim 1.4 \text{ kpc}$ , 2 active Nuclei

[Komossa+03]

- Natural expectation of hierarchical galaxy formation  
[e.g. Begelman+80]
- Discovery wide (kpc) BBHs
- Model of merger kick-off by asymmetric grav. wave emission  
[Komossa+08]
- Discovery of 1 narrow (7 pc) BBH  
[Rodriguez+09]
- Are there close to coalescence sub-pc scale BBHs?



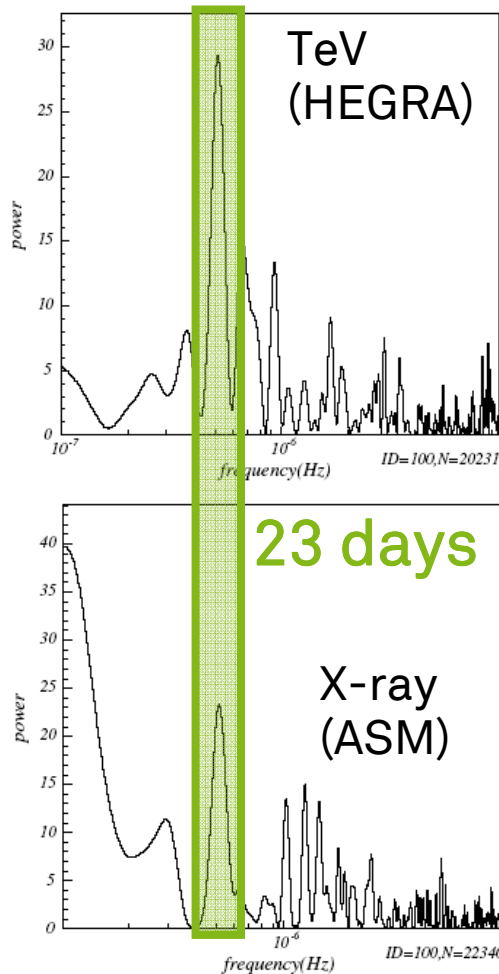


VLBI: HI-velocity

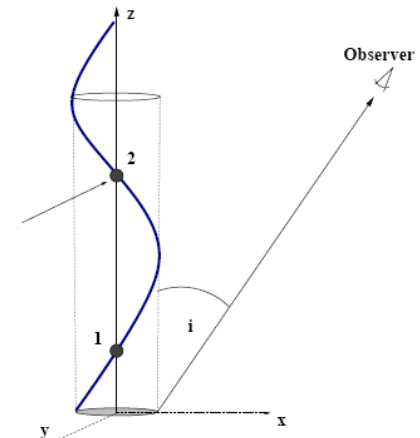
0402+379:  $z=0.055$ ;  $d \sim 7$  pc

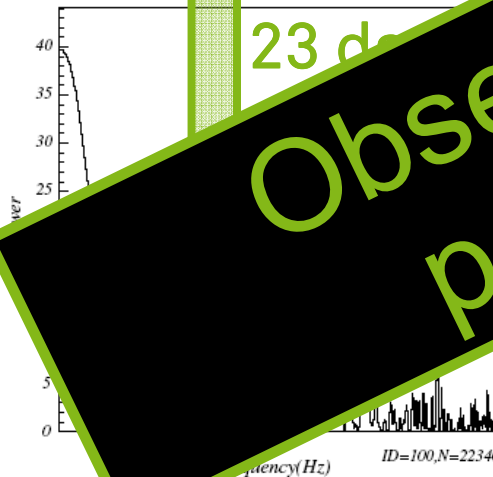
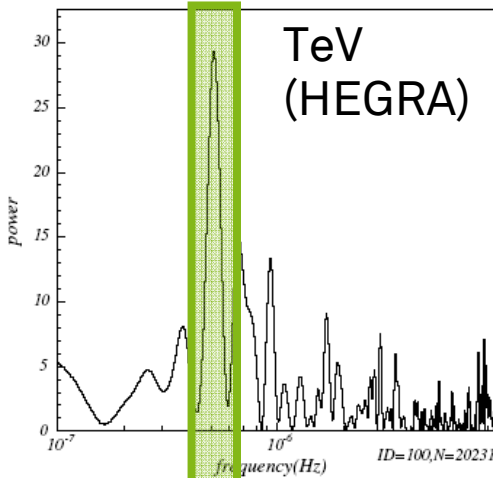
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- Theory: narrow BBHs would cause quasar like peak luminosities [Lobanov06]
- Not resolvable → Search for QPOs
- OJ287: 12 yr optical [Sillanpää+87, Fan+98, Wu+06]
- Mkn501: TeV & X-ray 23d [Kranich+99, Osone06]  
optical: 100d [Yang+08]  
new TeV & X-ray: 23d, 36d & 72d [Rödig+09]
- Interpretation of QPO in TeV as BBH [Rieger & Mannheim00, De Paolis+02, Rieger07]
- Extract mass & distance
- Calculate GW templates

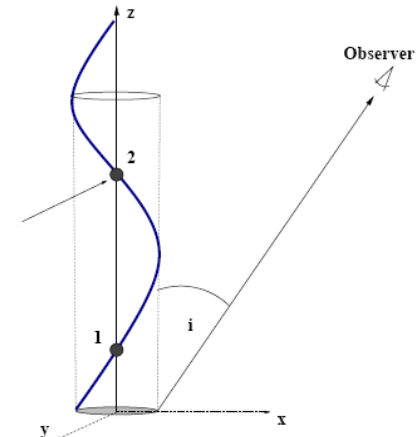




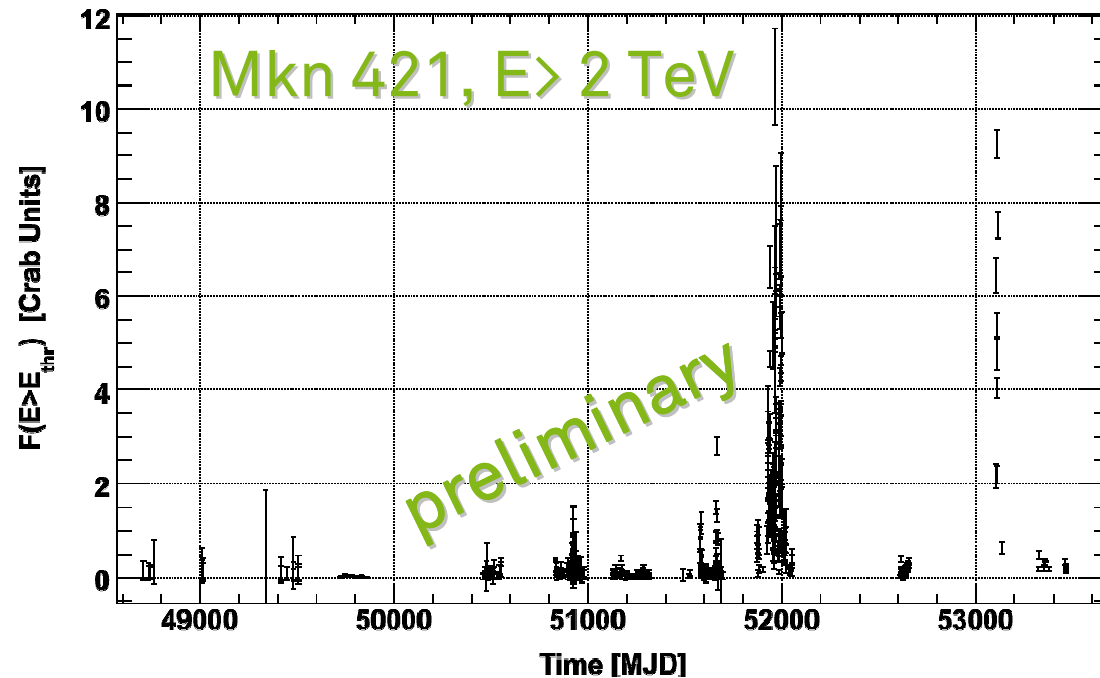
- Theory: narrow BBHs would like peak luminosities [Sar...v06]
- Not resolvable → [Sar...v06]
- OJ287: 12 y [Sar...v06]
- Mkn5 [Sar...v06]

**Observations of several periods mandatory!**

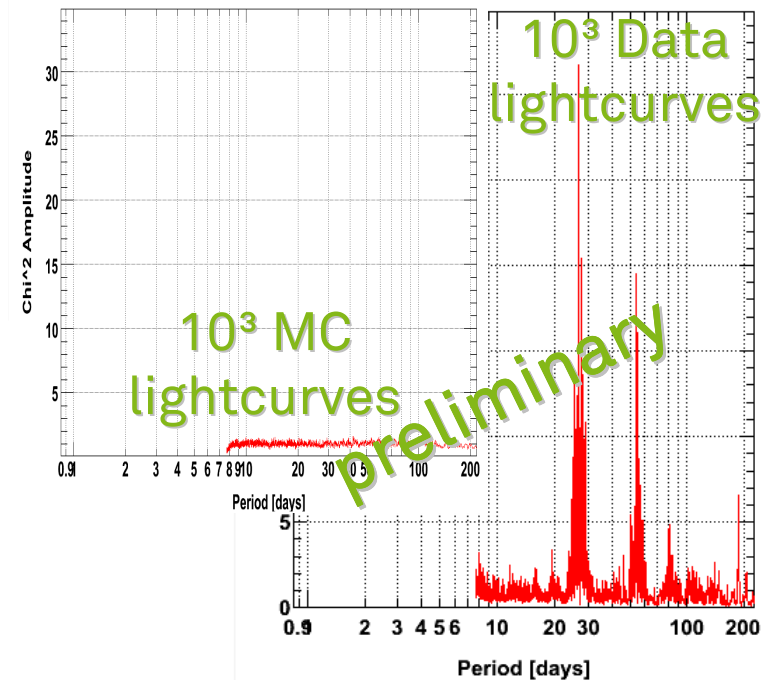
- ↳ Extract mass & distance
- ↳ Calculate GW templates



## Lightcurve



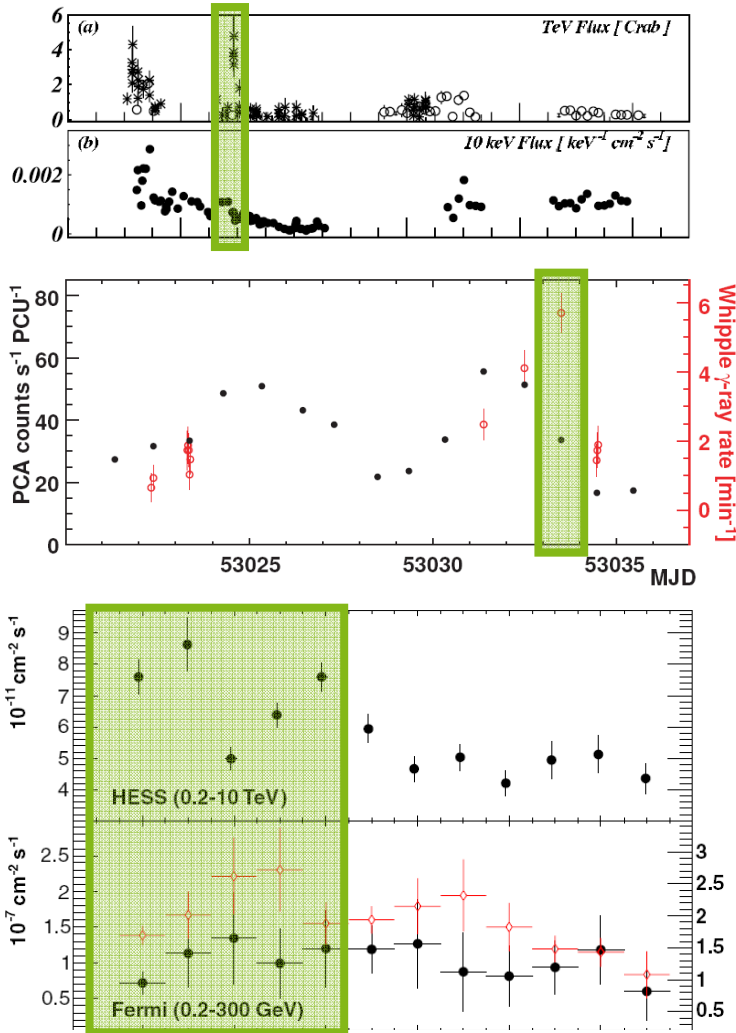
MC  $\chi^2$  amplitude DoD3 - red noise corrected



- Data collection still not complete
- Very first glance at the data quite encouraging:
  - 10<sup>3</sup> bootstraps, cleaned of trends of order 1 and 3
  - same for 10<sup>3</sup> MC lightcurves (flux and  $\Delta t$  distributions from data)

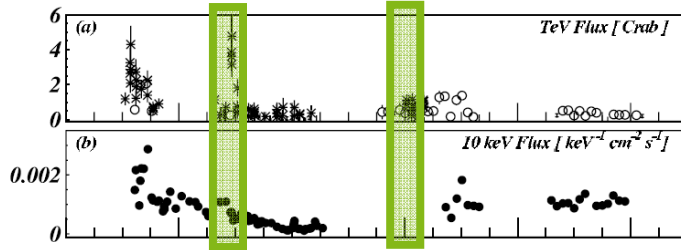


## Hadronic orphan flares?



- Orphan TeV flare in 2002 of 1ES1959+650 [Krawczynski+04]
  - „Orphan“ TeV flare in 2004 of Mkn 421 [Blazejowski+05]
  - PKS 2155-304: GeV lightcurve compatible with constant while in TeV highly variable [Aharonian+09]
- ➡ Different origins of radiation?





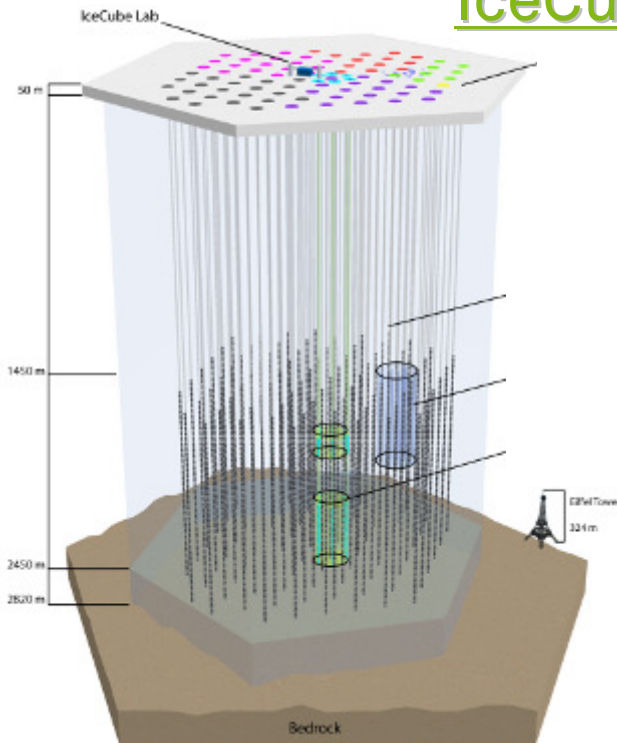
- 2  $\nu$  within 66 days, 1 coincident with orphan flare [Resconi05]

IceCube: ■ 1-2 atmos bg- $\nu$  / ( yr km<sup>3</sup> deg<sup>2</sup> ) [Halzen+06]

- flare of 2 crab in 1h with 1  $\nu$  /  
flare of 1 crab in 1d with 2  $\nu$   $> 4\sigma$  [Godman+07]

- Completeness of  $\gamma$ -ray data statistically crucial [Leier+06]

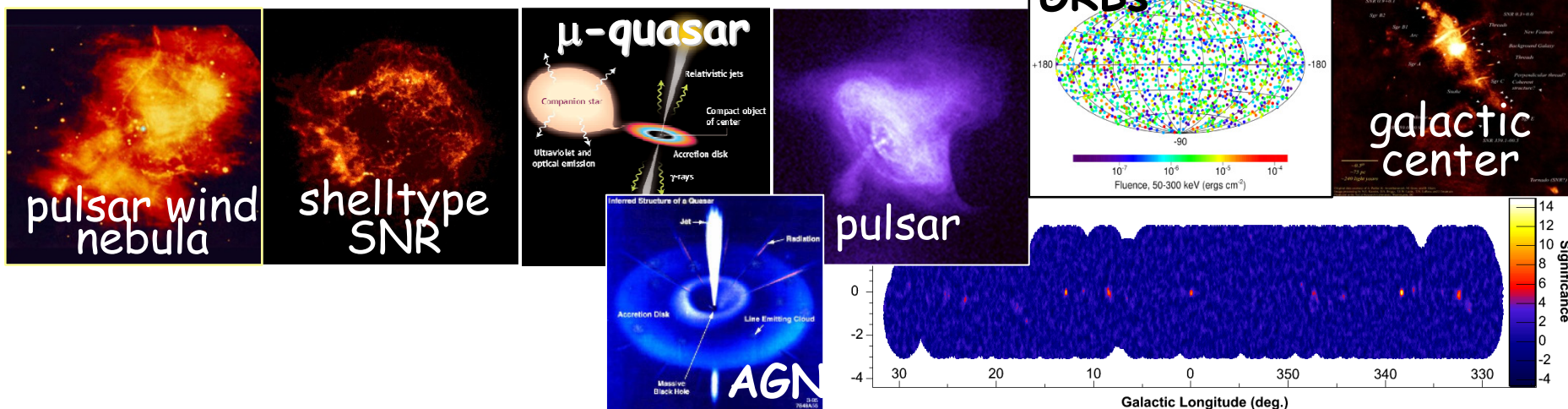
**Complete observations mandatory!**





High sensitivity with threshold energies around 100 GeV

⇒ many observation missions:

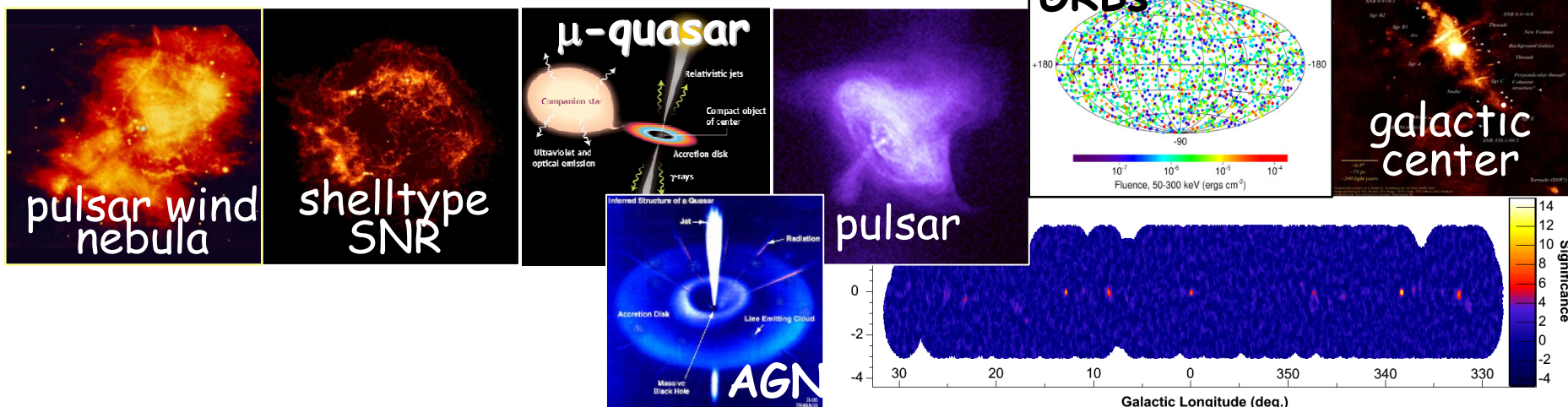


⇒ no cost efficient way for 24/7 monitoring



High sensitivity with threshold energies around 100 GeV

⇒ many observation missions:



⇒ no cost efficient way for 24/7 monitoring

→ **Dedicated Worldwide Agn  
Research Facility (DWARF)**

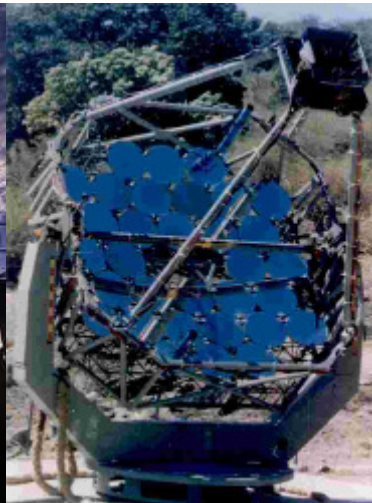


## Whipple 10m



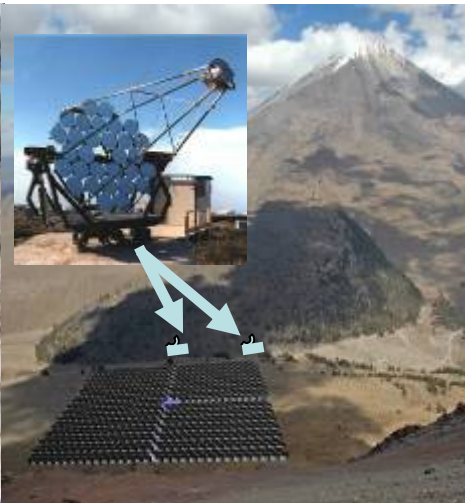
- 1 telescope
- Mt. Hopkins (Az, USA)
- ↳  $E_{th} \sim 400 \text{ GeV}$
- Ongoing monitoring  
[Pichel<sup>+</sup>, *ICRC09*]

## TACTIC



- 1 telescope
- Mt. Abu (IN)
- ↳  $E_{th} \sim 1 \text{ TeV}$
- Ongoing monitoring  
[Koul<sup>+</sup>, *NIM07*]

## OMEGA



- 2 of HEGRA
- Sierra Negra (MEX)
- **4100m a.s.l.**
- ↳  $E_{th} \sim 700 \text{ GeV} \rightarrow ???$   
[Ruben<sup>+</sup>, *ICRC09*]

## StarBase



- 2 of Telescope Array
- Utah (USA)
- $7.1 \text{ m}^2$  mirror
- Int. Interferrometry
- No Cherenkov-camera, **yet**  
[Finnegan<sup>+</sup>, *AIPC08*]

...  
more  
to  
come!



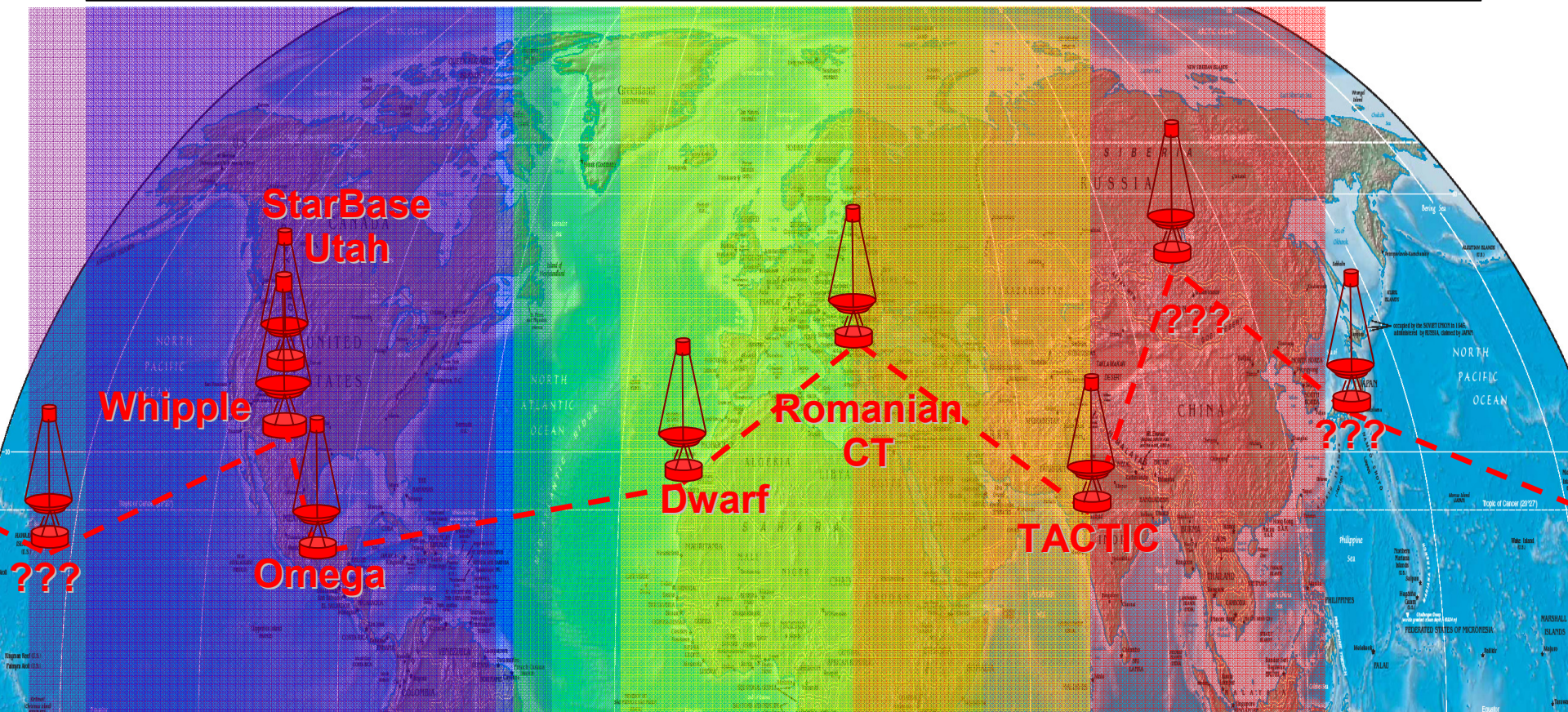




**D**edicated **W**orldwide **A**gn **R**esearch **F**acility  
**DWARF**







**D**edicated **W**orldwide **A**gn **R**esearch **F**acility  
**DWARF**





TU Dortmund, Uni Geneva, EPFL Lausanne, ISDC Versoix,  
PSI Villigen, Uni Würzburg, ETH Zurich, Uni Zurich

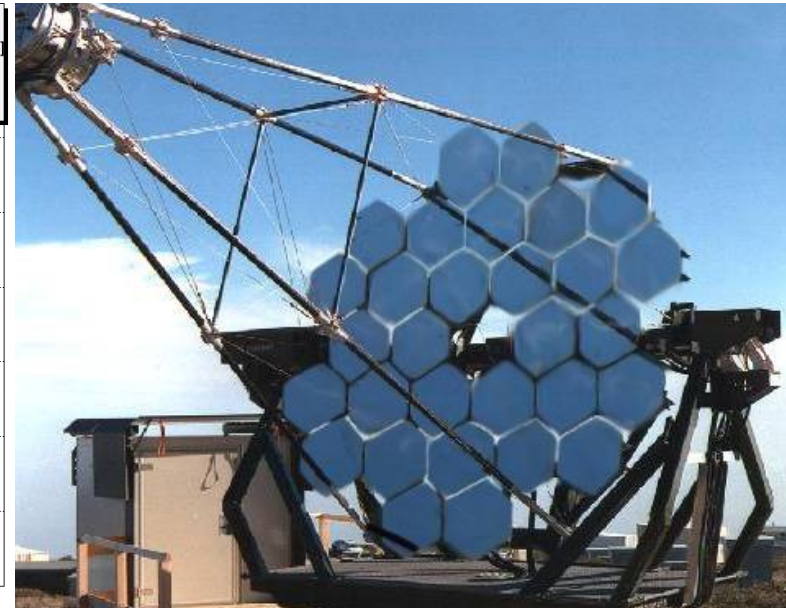
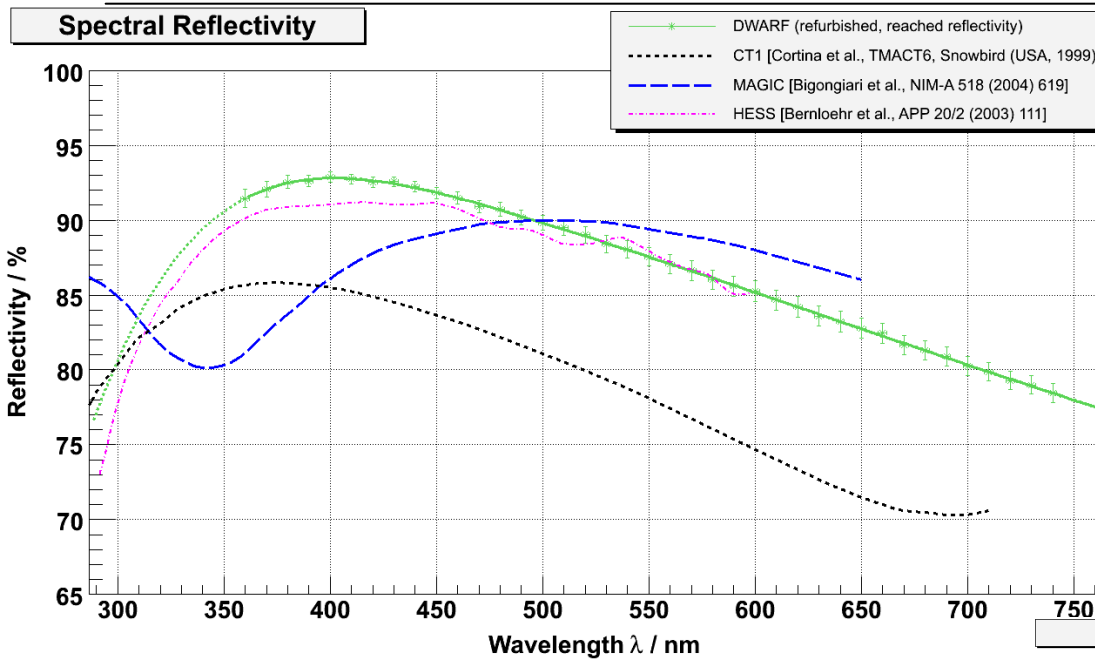


- Mount of former HEGRA CT3 on MAGIC site (La Palma)
- New drive system (as in M-II)
- New mirrors
- New G-APD camera, with solid light concentrators and embedded DAQ

↪ **Dominik**

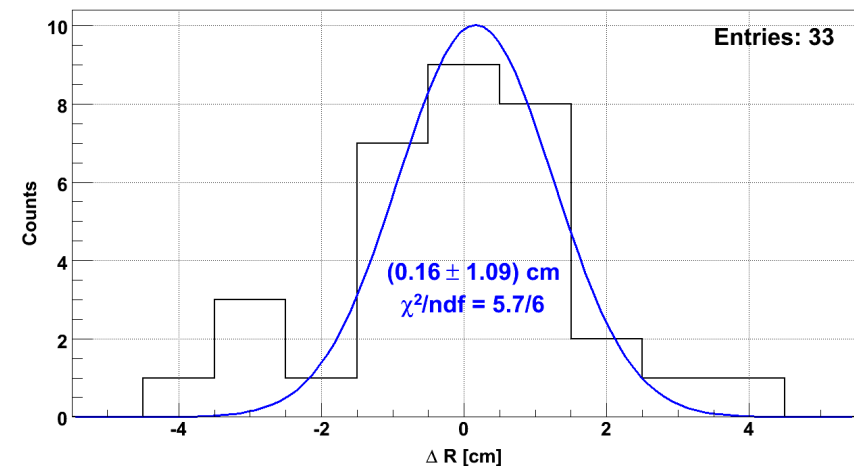
**MWL partners:** Metsähovi (radio), Tuorla (optical), Fermi (GeV)





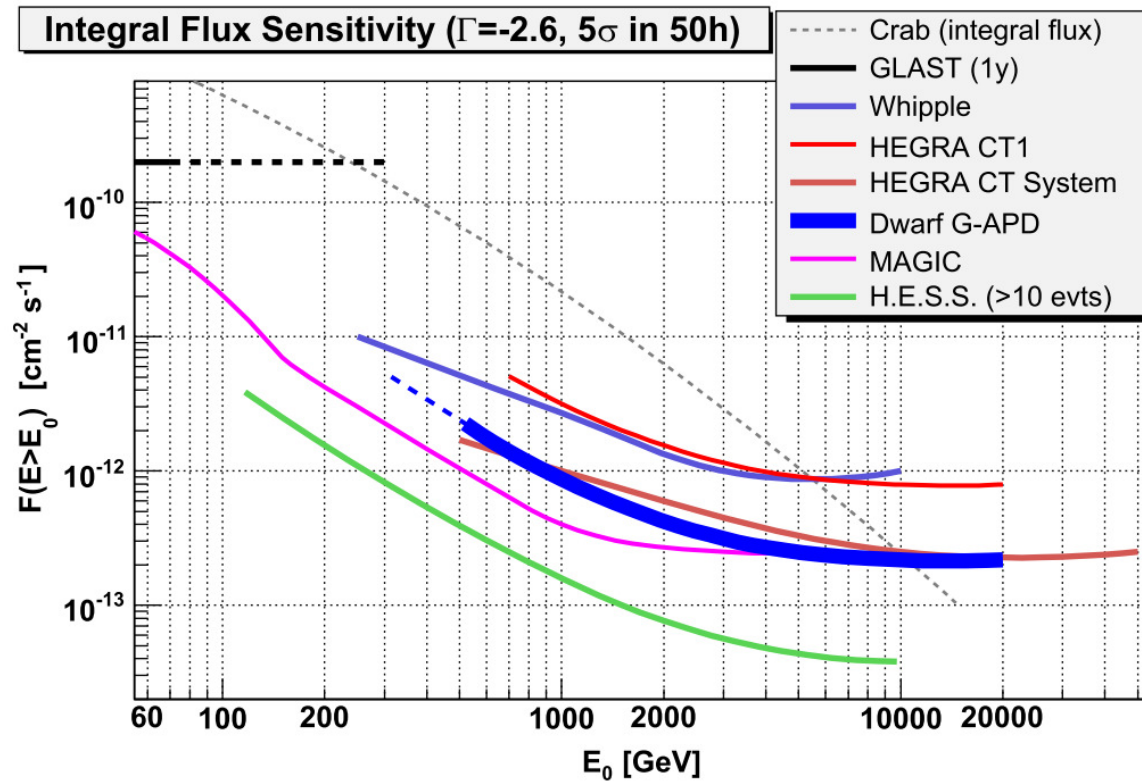
Deviation from nominal focal length (490cm)

- All-aluminum Mirrors from CT1 remachined and recoated
- Hexagonal → 9% enlargement
- ➡ 9,25m<sup>2</sup> mirror area



# The DWARF sensitivity

Improvement | Sensitivity  
gain



- Mirror area  
( $10.17\text{m}^2 \rightarrow 9.25\text{m}^2$ ) 0.95
- Reflectivity  
( $86\% \rightarrow 93\%$ ) 1.04
- GAPDs  
( $14\% \rightarrow 54\%$ ) 1.96
- Timing 1.40
- **Total gain comp.  
to CT1 2.73**

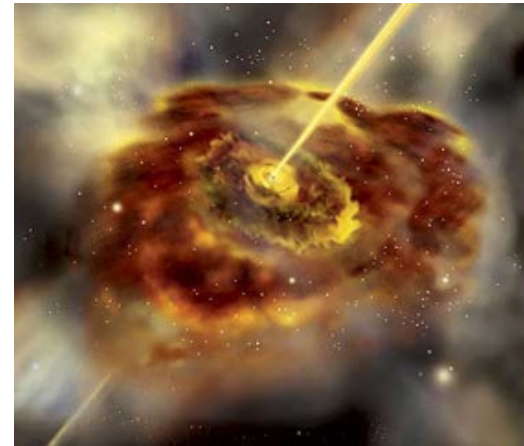
additionally:

- Wobble (3 off) 1.65
- **Gain obs. time 20.30**





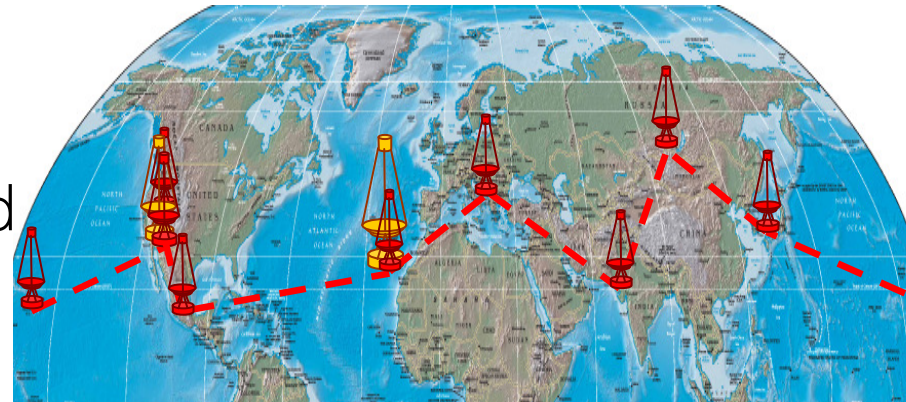
- Much interesting physics in monitoring, e.g.
  - Leptonic or hadronic jets?
  - Coincident  $\gamma$ - and  $\nu$ -observations
  - Super Massive Binary Black Holes
  - Gravitational waves



- Not cost-efficient with latest generation IACTs
- Dedicated telescopes for long-term monitoring of strong sources:

**DWARF**

Network of distributed  
telescopes for  
**24/7 observations**



A photograph of an astronomical telescope on a hill at sunset. The sky is a mix of blue, purple, and orange. The telescope is in the foreground, silhouetted against the bright horizon. There are some buildings in the background.

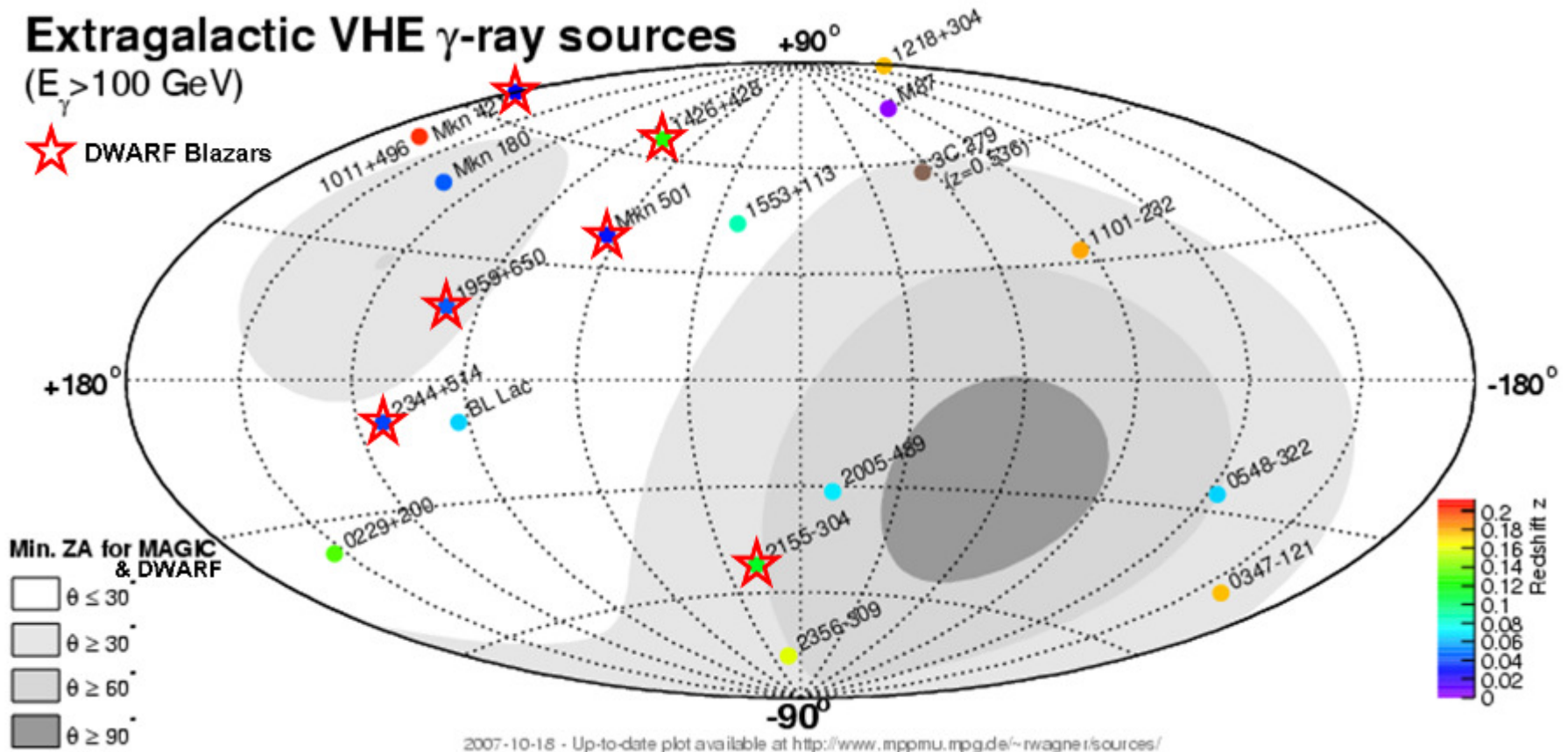
*Thank you!*

Dedicated **W**orldwide **A**gn **R**esearch **F**acility  
**DWARF**

## Extragalactic VHE $\gamma$ -ray sources

( $E_\gamma > 100$  GeV)

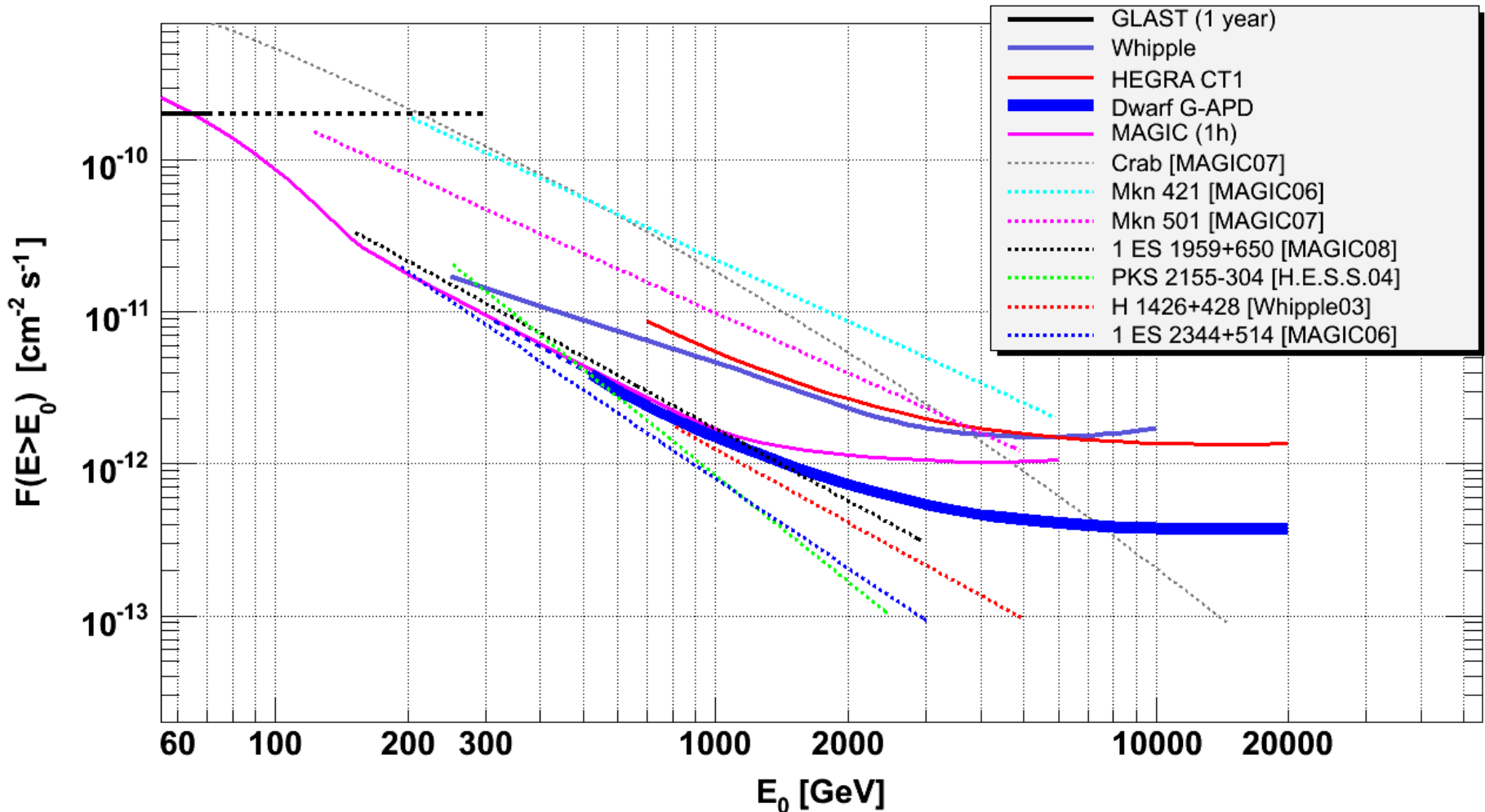
★ DWARF Blazars



Mkn 501, Mkn 421, 1ES 1959+650, 1ES 2344+514,  
H1426+428, PKS 2155-304



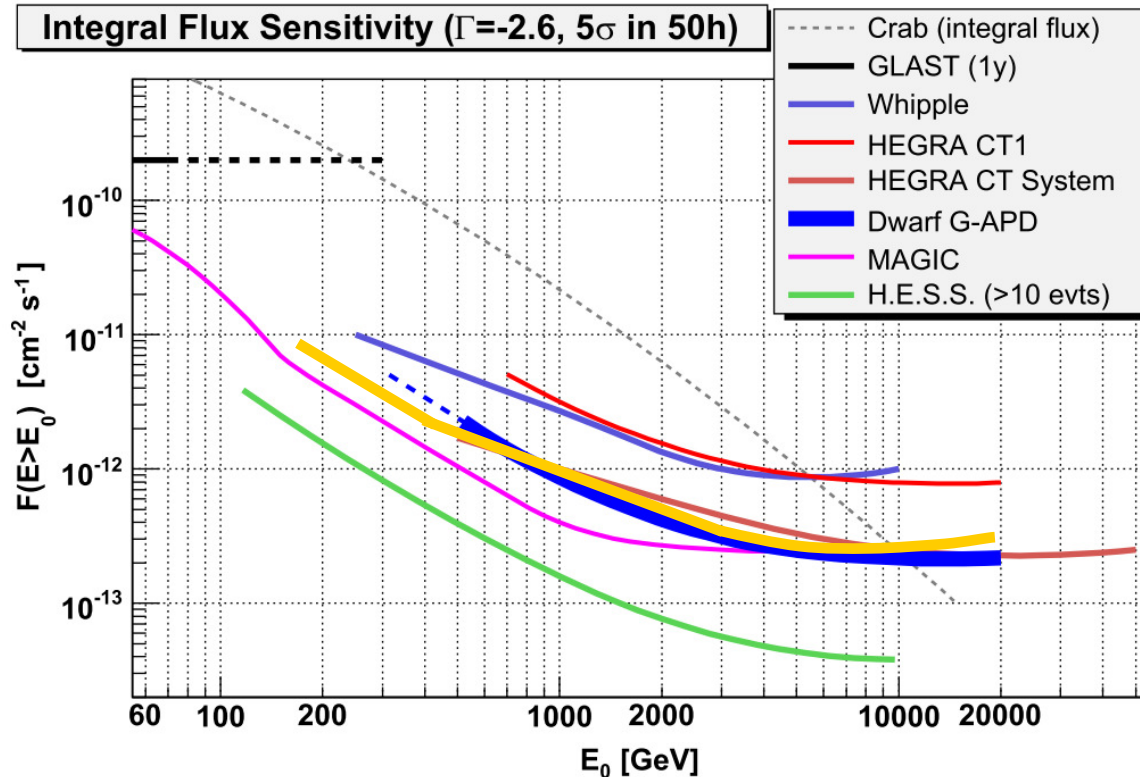
## Integral Fluxes and Flux Sensitivities ( $\Gamma=-2.6$ , $3\sigma$ in 6h)





Improvement | Sensitivity gain

Integral Flux Sensitivity ( $\Gamma=-2.6$ ,  $5\sigma$  in 50h)



- GAPDs (20%  $\rightarrow$  54%) 1.96
- Timing 1.40 ?
- ↪ Total gain comp. to Whipple now 2.30

additionally:

- Wobble (3 off) 1.65
- ↪ Gain obs. time 14.46
- (only 1.1 Timing) 8.93

